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Microfaciesof Yamama Formation in Selected Oil Field, Southern Iraq

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اقرار المشرف

أشهد بان موضوع البحث الموسوم.. والمنجز من قبل الطالب ....قد اجري تحت اشرافنا في قسم علم الارض كلية العلوم جامعة بابل كمتطلب جزئي لنيل شهادة البكلوريوس في علوم الارض وذلك للفترة من 2023/10/1 ولغاية 2024/4/1

التوقيع:

الاسم الثلاثي للسيد المشرف

اللقب العلمي:

التاريخ:

إهداء

الى خالق اللوح والقلم وبارئ الذر والنسم وخالق كل شيء من العدم

الى من بلغ الرسالة وادى الامانة .. ونصح الأمة .. الى نبي الرحمة ونور العالمين

الى السادات الاطهار وعروته الوثقى .. اهل بيت النبوة

الى مراد قلبي والاقرب لي من نفسي المغيب عن الابصار والكامن بعين البصيرة الى بقية الله الاعظم صاحب العصر والزمان (عجل الله فرجه)

الى تلك الحبيبة ذات القلب النقي ... الى من اوصاني الرحمن بها برا واحسانا الى من سعت وعانت من اجلي الى من كان دعائها سر نجاحي .. امي الحبيبة الى من اشاركهم لحظاتي .. الى من يفرحون لنجاحي وكانه نجاحهم .. اخوتي بكل حب اهديكم هذا الجهد المتواضع

الشكر والتقدير

اقدم شكري الجزيل الى عميد وعمادة كلية العلوم جامعة بابل لرعايتهم العلمية والتربوية القيمة طيلة فترة دراستي وإنجازي بحث التخرج. شكري وتقديري العميق لأستاذة المشرفه على البحث الاستاذه (مهى رزاق منهي) لاقتراحه موضوع البحث و توجيهاته العلمية النظرية القيمة ومساعدته العملية المتواصلة وتعاونه واخذ البيانات من منطقة البحث بشكل صحيح وسليم بالإضافة الى توفير المصادر العلمية المفيدة في البحث. كما أود أن أشكر رئيس قسم علم الارض التطبيقي (الدكتور مهند راسم عباس الجبوري) على تشجيعه المستمر ومتابعته مراحل انجاز البحث. والشكر موصول الى جميع أساتذة القسم الذين بذلوا كل جهد ووقت وعلم طيلة فترة اربع سنوات مدة دراستي في القسم، والذي تمكنت من خلالهم انجاز بحث التخرج المتواضع هذا.اقدم امتناني ومحبتي الى جميع زملائي الذين رافقوني فترة دراستي في قسم علم الارض وخاصة الزملاء الذين دعموني في انجاز العمل الحقلي لبحث التخرج.واقدم الشكر والتحية لجميع المعيدين والموظفين في القسم لجهودهم العلمية والعملية الرائعة طيلة فترة دراستي في القسم

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Summary

Yamama Formation represents an important carbonate reservoir of hydrocarbons of the Lower Cretaceous sequence southern Iraq that deposited within high stand system tract .

The lithologic description and petrographic examination indicated that most lithologic constituent of Yamama Formation is limestone in addition to the occurrence of shale and dolomite. The petrographic examination displayed that the skeletal grains composed of calcareous algae, benthic foraminifera, echinoids, mollusks and sponge spicules.

The non-skeletal grains include ooids, peloids and lithoclasts.

six main microfacies were recognized in the Yamama Formation: **mudstone, mudstone-wackeston, wackestone, wackestone- packstone, packstone, grainstone .**

Chapter One
Introduction

1-1 Preface:

In Iraq, the most productive interval is the Cretaceous succession which contains about 80% of the country's oil reserves. The Lower Cretaceous succession rocks have about 30% of Iraq's hydrocarbon reservoirs. Yamama Formation is recorded to contain hydrocarbons in 26 structures in south of Iraq.

The importance of Yamama reservoir is the containing of the highest quality oil, specifically in the Majnoon, West-Qurna , North-Rumaila, and Sindbad Oil Fields, while Tuba Oil Field consider not producing field.

1-2 Location of Study Area:

The studied area locates within Tuba and Sindbad oil Fields in Basrah Governorate: Two wells in Tuba Oil Field (Tu-2, Tu-3 Wells) and two wells in Sindbad Oil Field (Snd-2 and Snd-3)Wells. Table (1-1) and figure (1-1). Tuba Oil Field locate southern Iraq to about 40 Km at the south west of Basrah Governorate and situated between eastern Zubair Oil Field, (5Km distance) and western Rumaila Oil Field (2Km distance), (Alrrawi, *et. al*.,2015).Sindbad Oil Field locate southern Iraq to about (18Km) at the north-east of Basrah Governorate and (5Km) about Iraq-Iran borders, (O.E.C,2016,Unpulished study).

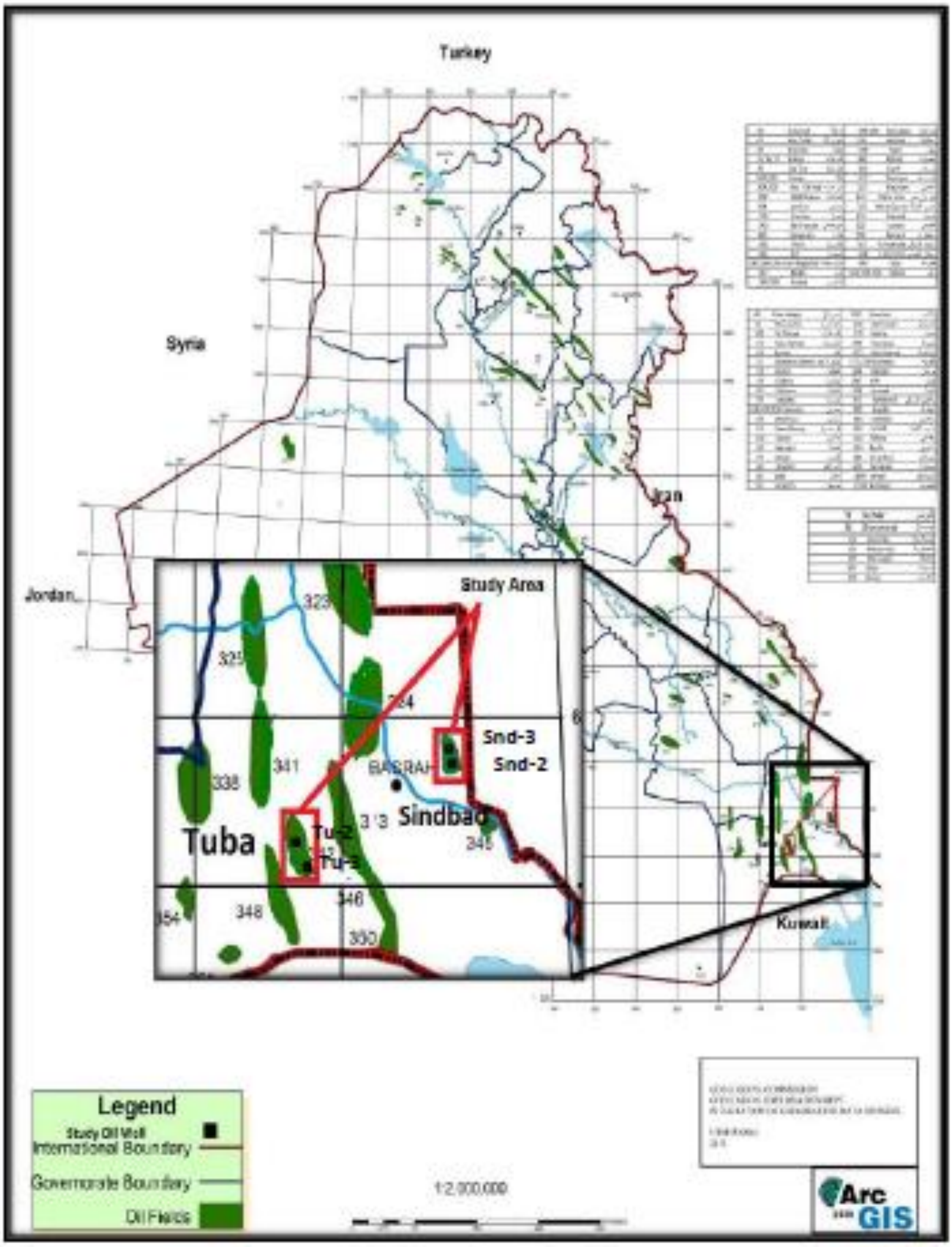

Figure (1-1): Locations map of the studied oil fields in the study area, from(O.E.C, 2016).

1-3Aims of study:

1- Lithological description of the studied formation in the studied oil wells.

2- Study the microfacies and define the sedimentary facies by the study of thin sections and determine the fossils that content in the studied oil wells.

3- Study the diagenesis processes that affect the studied formation in the studied oil wells.

1-4. Methodology:

Laboratory work: more than one fifty 50 thin sections had been prepared in the Applied Geology Department. Each sample was cut in different directions to investigate the fossils content.

Examination the samples under petrographic microscope to describe the microfacies and Describe the diagensis processes that effect on the porosity system of the studied formation.

1-5 Tectonic and Structural Setting

Tectonically, Iraq is divided in to three zones; Stable Shelf, Unstable Shelf and Zagros Suture Zone, figure (1-2). Mesopotamian Zone belongs to the Stable Shelf covers by Quaternary sediments and overlying the whole Mesozoic and Cenozoic sections, (Jassim and Goff, 2006).

The extension of the studied formation basin over two tectonic zones (Mesopotamia & Salman Zones) and there tectonic subzones had been played a significant control for the final shaping and configuration of the Yamama basin, (Sadooni,1993).The location of the study area is within Zubair Subzone at the southernmost unit of the Mesopotamian zone .The Zubair Subzone is bordered by a transversal fault zone of Takhadid-Qurna fault which formed during the Late Precambrian at the north, Al-Batin fault at the south or along the transversal fault in Kuwait, and Salman Zone from the west, (Jassim and Goff , 2006). Tuba and Sindbad Oil Fields are a dome structures and there axis trending north northwest to the south southeast (Alrrawi, et. al.,2015). Sindbad Oil Field covers by (78m) of recent alluvial deposits, (S.O.C., 2013).The history of Mesopotamian Basin could be divided into two phases: first one, is the opening phase which is characterized by divergent plate boundaries which formed a passive margins when the plates moved apart from each other and the second is: closing phase, represented by convergent plate boundaries which formed an active margins when one plate moved toward another, (Almutury and Al-Asadi, 2008).These two phases extended from Early-Mid Permian to the Turonian, (Jassim and Goff ,2006).Mesopotamian Zone has three genetic types of subsurface folds which buried by Quaternary deposits. Generally the type of folds in the southernmost basin are N-S trending followed the inherited old fractures

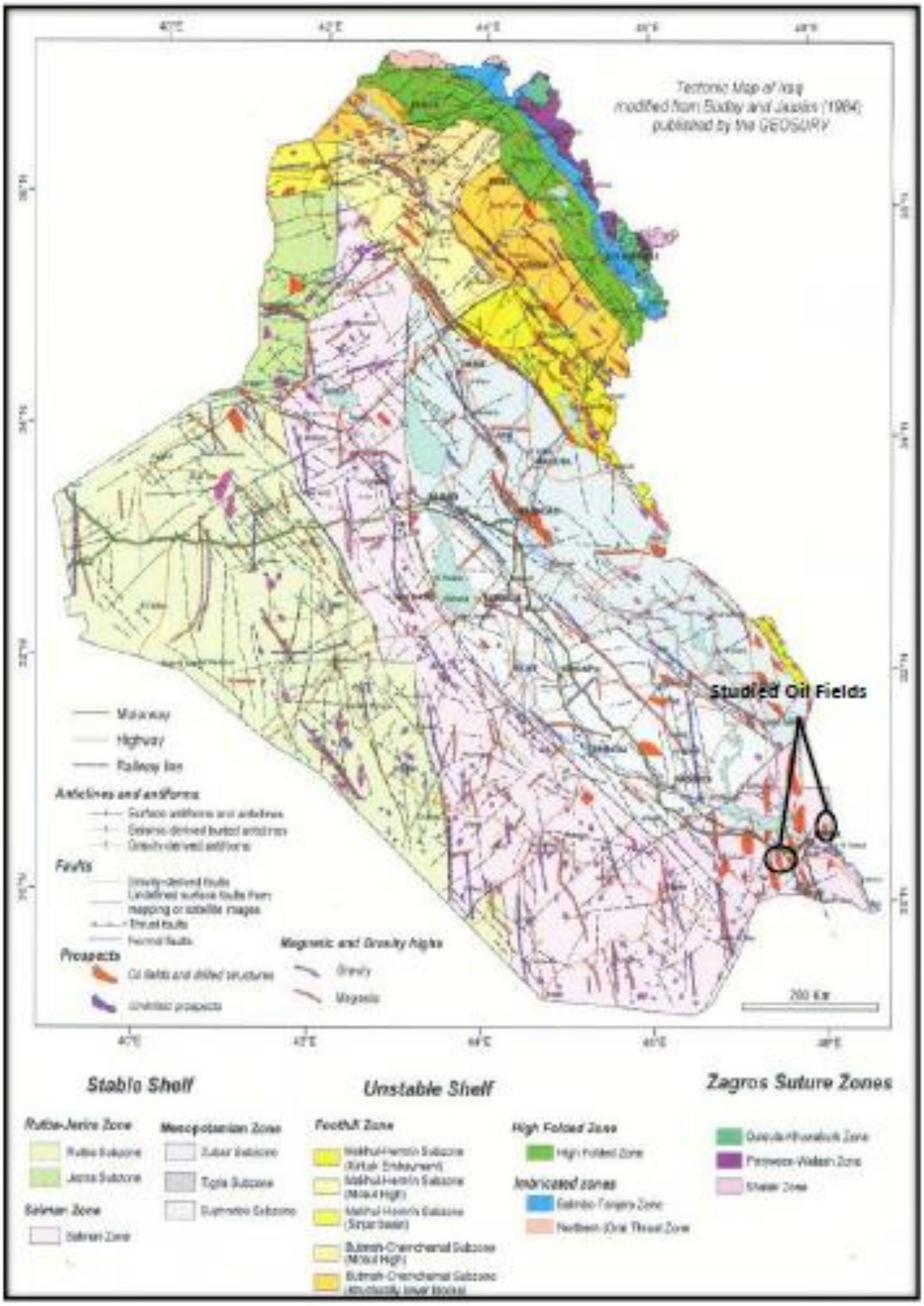

Figure (1-2): Tectonic map of Iraq, (After Jassim and Goff, 2006).

.The folds are usually has low amplitudes, broad and long, (Fouad& Sissakian 2010), to about hundreds of Kilometers towards Kuwait and eastern of Saudi Arabia. At Lower Cretaceous the amplitudes of these structures increase up to 300 meter, (Jassim and Goff ,2006).

Mesopotamian Zone suffered from several subsidences during Mesozoic and Cenozoic resulted from the occurrence of subsurface faults within basement rocks, (O.E.C., 2016).

The seismic surveys and investigation studies of Mesopotamian Zone that carried by the Iraqi Oil Company proved the existence of different sizes structures, generally N-S trending anticlines and synclines, (Lazim,2006).

The occurrence of the Late Precambrian Hormuz Salt deposits and its active movement northern of the Arabian Gulf area result in development of these folds,(Fouad& Sissakian, 2010).These structures are created during the Late Nabita.

Orogeny then, it reactivated during Permocarboniferous, Mesozoic and even during Tertiary time, (Jassim and Goff , 2006).

The salt accumulations prefere to exist in rift basins. The Hormuz Salt sediments are underlining the Paleozoic clastic deposits of the Saq, Khabour, and Gaa'ra formations. The depositions of Mesozoic carbonate was based upon these clastics, (Sadooni, 1993).

The Early Cretaceous time was a stage of transgression and forms an openshelf environments over most of the province. The wide carbonate platform continued to exist and the carbonate-shelf circumstances replaced the differentiated carbonate shelf with the ramp environments, (Alsharhan, 2014). At this time, the central Iran and Arabian Platform were passive margins at the opposing rift shoulders that bordering NeoTethys ocean, (Van Buchem et al.2010), figure (1-3) . The movement of the plate was exchanging from the south to the north in Albian . The Equatorial Atlantic opening occored at the same time coinsiding with the

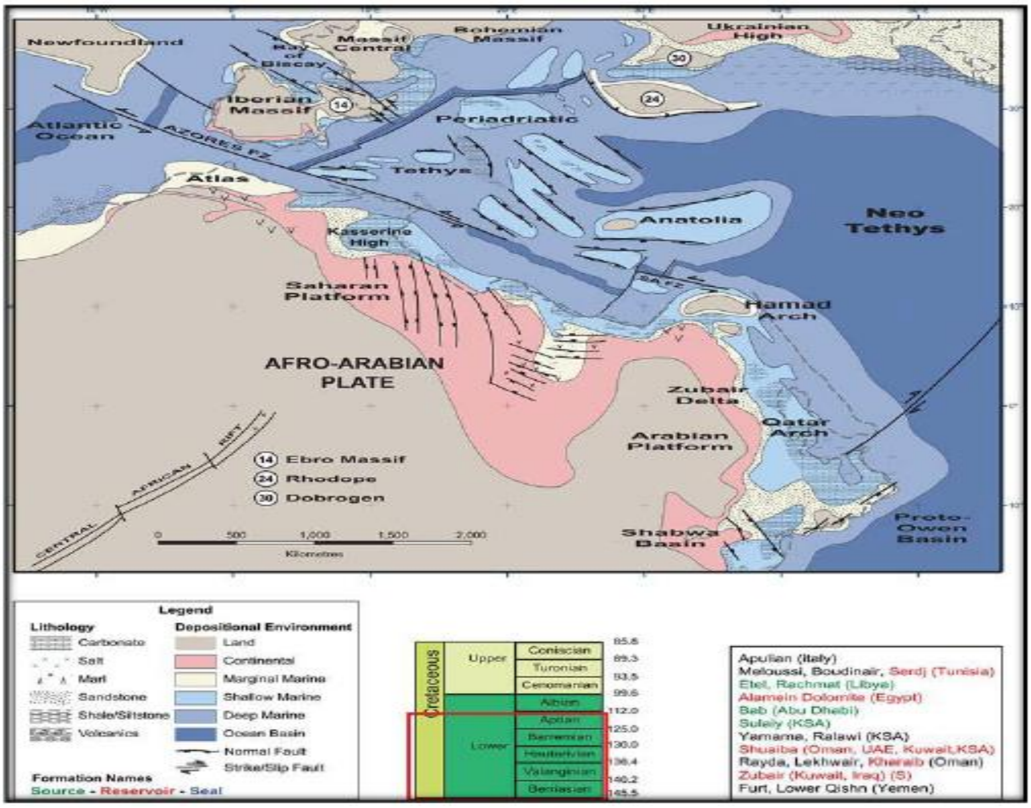

Figure (1-3): Palaeogeographic map of Lower - Cretaceous secession illustrate carbonate depositional environment, (After Van Buchem *et. al*., 2010).

During the Middle Cretaceous, the wide margin of Arabian Plate initiated the development of a northeast-dipping subduction zone in the Tethyan Ocean. During the movement of plate progressively north-eastwards it collided with this subduction zone, resulting in the obduction of thrust slices of Tethyan ocean floor onto the NE margin of the Arabian Platform, (Alsharhan, 2014).Both of the Cretaceous & Paleocene periods form a pre-colloidal plate tectonic. Finally, The end of the Wilson Cycle was in the Eocene which spaned to about 200Ma .The large number of Cretaceous formations(40) compared with its duration (71Ma) is due to the higher tectonisms compared with earlier Phanerozoic times which has (35) formations for (434 Ma) in Paleozoic, Triassic and Jurassic, (Numan,2000).

1-6 Previous Studies:

The first definition for the studied formation was in 1952 by Steinke and Bramkamp where they described outcrops in Saudi Arabia as recrystallized oolitic and detrital limestone interbeded with sandy shale and subjoint to the Thamama Group beside Sulaiy and Buaib formations.

In Iraq, Rabanit (1952) in Dunnington, (1959), described The Sulaiy /Yamama type section in Rt-1 well and afforded it the age of Tithonian - Berriassian.

Dunnington(1959),Referred to the formation as a combined(Yamama/Sulaiy) characterized by peloidal limestone overlain by the Ratawi formation.

Chatton and Hart (1962), defined the Ratawi Formation, and designated the Ratawi Formation consists of clastic facies and include shale, sandstone and siltstones , on the other hand, Yamama Formation was consisting of carbonate facies.

Ditmar,*at.,al*., (1971), mentioned that the Yamama Formation is equivalent to the Zangura&Garague Formations in the north of Iraq,by paleontological contents allthough the difference of lithology .

Fluoria (1976), indicated that the yamama formation comprises a series of sedimentary cycles, each cycle contains dense argillaceous mudstone evolving upward to the porous grainstones.

Al-Siddiki (1977), divided Yamama Formation into three main lithofacies,the first one at the top is the with high porosity and permeability of oolitic limestone,the second is fine crystaltine, dense limestone and the third lithofacies at the bottom is the permeable, porous carbonate composed of reworked detritus.

Al-Siddiki (1978), divided Yamama Formation into three reservoir units; (YA ,YB ,YC) and these units subdivided into YA1, YA2.......et.

Sadooni (1993, a, b) studied the depositional system of the Yamama Formation of the West Qurna Oil Field, he divided the Yamama Formation into an upper part (60-80m) that includes two units, the peloidal grainstone –algalwack to packstone, and reefal boundstone, so the effects of barriers at the shelf edge directly on the composition of shelf facies. Sadooni divided the Yamama Formation into two lithostratigraphic units (A and B) separated by barriers, also he referred to the correlation between Yamama Formation to the middle oolitic unit of the Minagish Oil Field in Kuwait.

Saleh (1999), mentioned that the Yamama / Sulaiy succession is deposited in shallow ramp setting dipping gently towards the east. The disappearance of *pseudocyclamina littus* and *Trocholina elongate* may indicate the Sulaiy Formation.

AL-Obaidi, (2001),Studied the depositional system of the Yamama Formation of the Ratawi Oil Field, Indicated that six type of microfacies and he study the clay minerals and there effects on reservoir properties and porous system.

Mutlak, (2004), mentioned that the age of Yamama Formation is late Berriasian - Early Hauterivian. The lithology consist of oolitic, pseudo-oolitic –peloidal grainstone microfacies and dolomite with sand influxes which are deposited on abroad ramp platform.

Al- Issae, (2012), studied the Yamama Formation in Ratawi Oil Field and pointed out that the second reservoir unit (YB) has the best reservoir properties which has highly pay zone.

Al-Hakeem, (2014), Studied the Yamama Formation in Ratawi Oil Field and pointed out that the Yamama Formation in the studied field has distinctive reservoir property at the crest of the formation reducing towards the flanks especially towards the eastern flank around (Rt-4) due to diagenesis processes, and has good reservoir property at the top of the formation reducing downward the formation.

Altala & Mahdi, (2018) studied Yamama Formation in Gharaf Oil Filed and pointed out that the reservoir unit Y2 of shoal facies is the major reservoir unit characterized by high effective porosity.Although units Y5 and Y7 have similar shoal facies with unitY2, they exhibit lower reservoir quality due to lower values of porosity. This change in reservoir characteristics is related to cementation process.

T. G. Al Mafraji & A. A. Al-Zaidy,(2019) studied Yamama Formation in Luhais and Rachi oil fields. They recognized six main microfacies for three association facies. These are the Semi-restricted, Shallow open marine and Shoal environments. The study succession represents deposition of three third order cycles, these cycles where deposited during successive episodes of relative sea level rises and still stand.

Chapter Two

Microfacies

2-1 Preface:

The microfacies term belong to sedimentary facies that its characteristics could be studied in thin sections under petrographic microscope or by similar techniques such as paleontological techniques isotopes, scanning electron microscopy, chemical, X-ray diffraction analysis, but the petrographic microscopic analysis remains the principal method for studying the microfacies. The microfaces is the total of all paleontological and sedimentological data which can be described and classified in thin sections, peels, pulished slabs, (Flugel 2010).

The purposiveness of microfacies analysis is to offer a details about the components of carbonate rock properties (growth forms and kinds of fossils,

cement, size and shape of grains, carbonate grain types, particle fabrics, nature of micrite) that can then be related to depositional circumstances ,so the environmental interpretation is the final aim of microfacies analysis, (Boggs,2009).

There are two main aims for classification systems of microfacies: (1) To make systematic and reproducible descriptions of fundamental rock properties and (2) Facilitate information transfer, (Ahr, 2008).

Dunham classification is the most widely used and simplest classification, (Tucker and Wright, 2002) because the terms are easier and shorter to record when working on large amounts of rocks and they seem to induce emotional images of rock characteristics that reservoir properties could be expected, (Ahr, 2008). Dunham's rock classes are based on the occurrence or absense of carbonate mud, the occurrence or absence of organic binding, and the conception of matrix support against grains, (Moore ,2001) .

The Dunham classification for detrital carbonates has the ability to tell the flux energy. It is common practice to imagine that the grain - rich rocks indicate high - energy environments and mud - rich rocks indicate low - energy environments(Ahr, 2008).

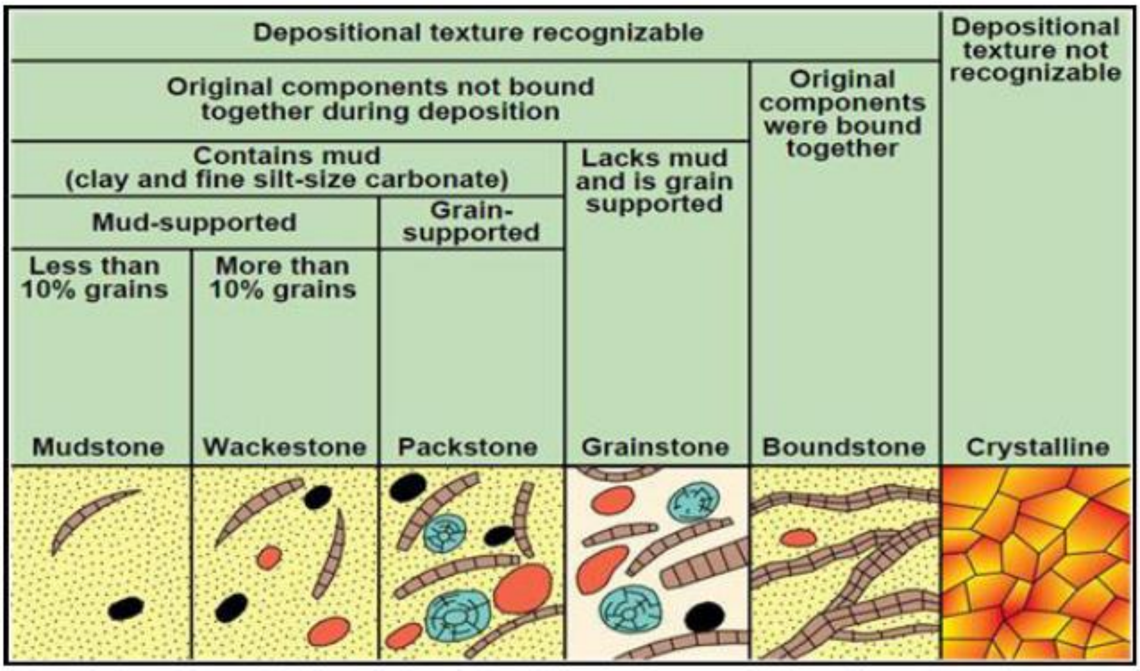

Figure (2-1): Dunham classification of carbonate rocks, (After Dunham, 1962).

2-2: Petrographic Constituents:

Limestones are a highly varied in composition despite the simplicity of mineralogy. Three main constituents can be recognized in the Yamama Formation: grains, matrix and cement. Grains can be additional subdivided into skeletal grains and non- skeletal grains, (Tucker and Wright, 2002).

2-2-1 Grains:

2-2-1-1: Skeletal grains:

Skeletal fragments in the carbonate sediments are the whole or broken grains of the hard parts of organism bodies that use minerals of calcium carbonate as a part of their structure, (Nicholas, 2009).

The great used of the fossils is the environmental interpretation of the sediments. It can tell about the turbulence level, water depth,sedimentation rate, and salinity, (Tucker, 2001).

The range sizes of skeletal grains vary in thin sections, it have a range from less than (1mm) to several centimeters. The transport processes lead to the diminution in the sizes and patterns of skeletal grains that depend on hydraulic modifications, (Flugel, 2010).

Many types of skeletal grains had been identified within Yamama Formation such as benthic foraminifera, echinoderms, algae, bivalve fragments, sponge spicules, ostracods and other organisms where some of them are affected by diagenesis processes and make diagnostic some of them is difficult.

2-2-1-1-1 Foraminifera:

Foraminifera are consider a brilliant environmental proxies, making the ancient depositional schemes to be reconstructed and provide time signs for biozonations of deep and shallow marine environment. Foraminifera are marine heterotrophic protests that built chambered shells (tests). The two major groups of foraminifera are planktonic which living within the upper 100 m of the oceans and benthic foraminifera which living on or in the sediments of the sea floor.The foraminifera that living in shelf limestones are vital reservoir rocks for hydrocarbons, (Flugel, 2010).

Typically, The range size of foraminifera is(<0.1 mm to 1 mm) ; the largest size may reach to about 20 cm. Modern foraminifers are spreading from the abyssal ocean to intertidal zone, from polar cold water to warm tropical water.Some genera live in marginal, restricted marine hyper saline water or sub saline water area where they are commonly found in a huge numbers with low species diversity, (Scholle & Scholle, 2003). Benthic foraminifera were the dominant shallower-water carbonate producers, especially in the deeper photic zone, (Reading,1996). Benthic foraminifera is the most skeletal grains that dominant in the Yamama Formation, these are:

Textularid sp. According to Saleh (1999), the disappearance of the last two spices may indicate the presence of Sulaiy Formation. It is found as a main elements or associated with the other skeletal fragments.

2-2-1-1-2 Calcareous Green Algae:

Green algae generally are most common at depths of 2 to 30 meters, but some heavily calcified modern codiaceans are most abundant at depths of 50-100 m; a few forms extend into water depths greater than 100 m. Wide salinity tolerance ranging from strongly hyper saline to brackish. Most calcified forms develop mostly in warm temperate to tropical areas with near-normal salinity waters. Skeletal mineralogy essentially all aragonite, (Scholle and Scholle, 2003). The most common algae that diagnosed in the Yamama Formation are dasyclad green algae.

2-2-1-1-3 Calcispheres:

A hollow spherical microfossils commonly its diameter < 500 micron and displaying calcitic walls. These fossils are interpreted as algal remains. Cretaceous spherical microfossils are mostly found in deep environment, (Flugel, 2010).

2-1-1-4 Other skeletal grains:

There are many skeletal grains that were recognized in the Yamama Formation within the studied wells such as: gastropod ,ostracod,Pl(9-3), echinoid spin, echinoid fragment , brachiopods, Pl. (11-6).

2-2 -1-2: Non Skeletal Grains:

The grains that are not clearly derived from the skeletal grains. Three main types are recognized: peloids, lithoclasts, and coated grains, (Tucker and Wright,2002). In the Yamama Formation these types had been recognized and coated grains was represented by cortoids and ooids.

2-2-1-2-1 Peloids:

Peloids are un inclusive description term include polygenetic group of grains comprise of crypto - and microcrystalline carbonate. Peloids are commonly internally structureless but it may have fine-grained of skeletal remains in addition to the other grains. Generally, the typical sedimentation of fine grained peloidal limestones are, low-energy, restricted, shallow marine environments, (Flugel,2010).

The most common sizes of peloids range from 0.05 mm to 0.20 mm. They may occur in cluster and they are commonly well sorted, (Boggs. 2009). Peloids are generally spherical, ellipsoidal rounded or sub rounded, to irregular in shape and commonly has high organic contents. Fecal pellets, produced by deposit-feeding animals, (Tucker and Wright, 2002).

The biological disintegration or micritization of other carbonate grains (mainly bioclasts or ooids) form peloids that may retain slight traces of their original internal structure, (Scholle and Scholle, 2003).Figure (2-2)

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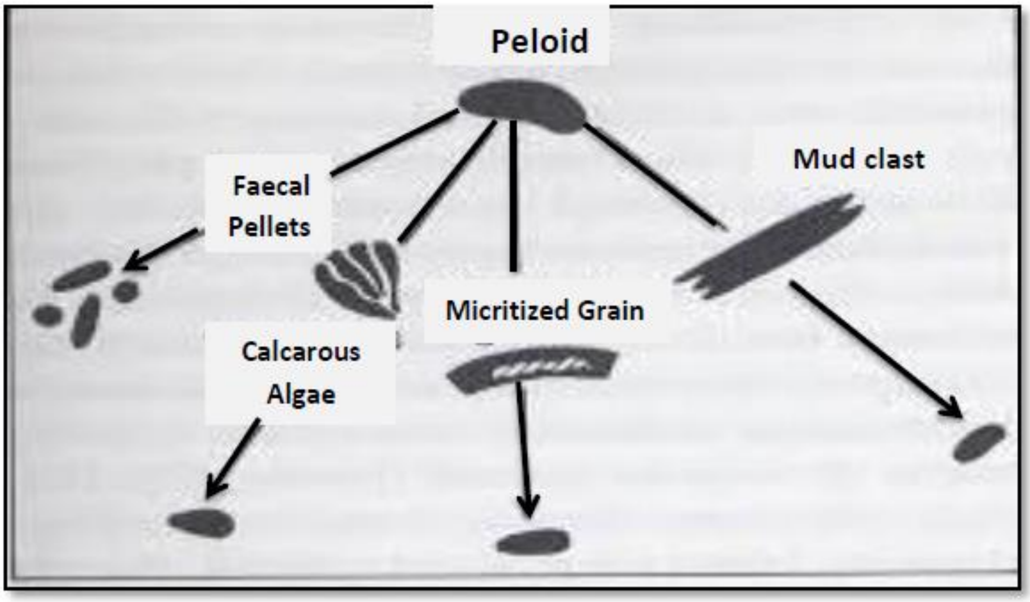

Figure (2-2): Origins of peloids, (After Tucker and Wright, 2002).

2-2-1-2-2Coated grains:

Coated grains are all of the carbonate grains that contain a nucleus surrounded by an encircle layer or layers generally called the cortex, (Boggs, 2009). The difficult use of coated grains as environmental interpretation is because of the similarity forming process of coated grains in very different environments, , (Tucker and Wright, 2002).

2-2-1-2-2-1 Ooids:

Ooids are ovoid and spherical of carbonate and have a nucleus covered by an external cortex. The diameter of most ooids is smaller than 2 mm and many ooids between 0.5 to about 1 mm in size, (Flugel, 2010). The nucleus may be a peloid, smaller ooid, skeletal fragment, or even a clastic grain such as a quartz grain. Carbonate grains that are larger than about 2 mm and structurally similar to ooids called pisoids. Ooids can be deposited in a wide variety of environments, but Commonly, ooids deposit in shallow carbonate platforms, (Boggs, 2009). According to Flugel (2010), there are three ooid categories;1) Concentric (tangential) ooids formed in high-energy marine environments which is seldom well preserved in ancient ooids , 2) Radial-fibrous ooid form in low-energy marine, 3) Micrite ooids formed by activity of microborers displaying neither radial nor concentric microfabrics.

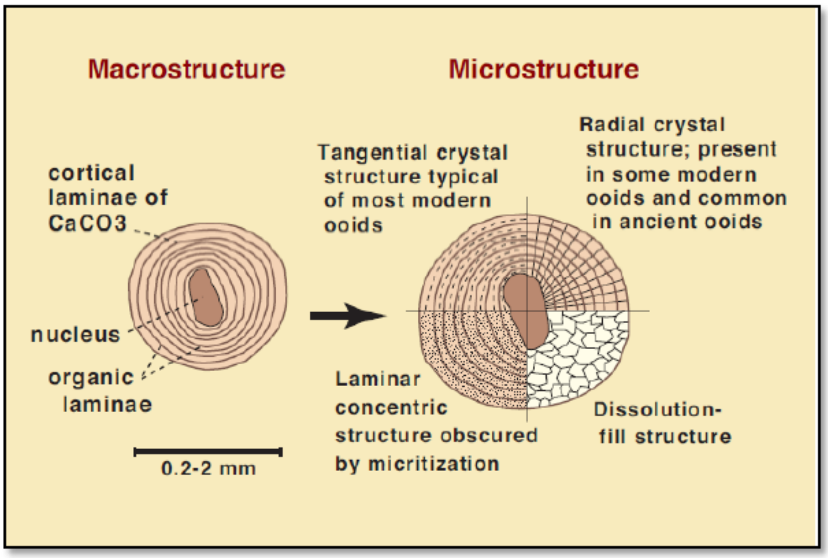

Figure (2-3): The structural and diagenetic patterns of ooids, (After ScholleScholle,2003).

2-2-1-2-3 Intraclasts & Extraclast:

An intraclasts are a partly lithified or completely lithified sediments of carbonate fragment, forming by the erosion of adjacent of pen contemporaneous sediments from Extra-,Intra- and Lithoclasts within the basin then re- deposited in the same area. The extraclasts are a fragment of carbonate rocks forming by the erosion of the exposed ancient rocks of limestone and coming from the outside of the depositional basin in which it is found. There are a difficulties in the segregation of the two types in thin sections, so the term lithoclasts had been used by many authors

(Flugel, 2010), limeclast or limestone clast is suitable, (Tucker and Wright, 2002). Table (2-1) explains the major properties of extraclast. Lithoclast was recognized in Tu-2 and Tu-3 Wells, Pl. (3-1and 8-2).

2-2-2 Matrix (Groundmass):

The term matrix refers to the fine interstitial substantials floating among larger grains. Generally, the (matrix) term is synonymous with the term of (groundmass) (Flugel, 2010).The matrix comprise of fine-grain material such as microspar, micrite, and calcisiltite, but these terms being used by some authors to specify both coarse interstitial crystal fabrics of sparite and fine-grained interstitial
material of. micrite. Depending on the differences in composition and grain size, three categories of matrix (groundmass) can be distinguished; Micrite, Microspar, Calcisiltite, (Flugel, 2010).

2-2-2-1 Micrite:

Carbonate mud is termed micrite, (Selley, 2000), and it is the abbreviation of ‘microcrystalline calcite’. In fact, ‘micrite’ was proposed by (Folk 1959) referring to the lime mud deposits that mechanically lithified, (Flugel, 2010). Micrite is the fine-grained constituent of carbonate grains and the fine grained matrix of carbonate rocks. The size of micrite crystal ranges from cryptocrystalline (cant be resolvable under the petrographic microscope) to microcrystalline.

Generally, the existence of micrite give assign of low-energy depositional environments in both of deep and shallow marine, (Flugel, 2010).

Micrite may be replaced to form microspar by diagenetic alteration through aggrading neomorphism, (Tucker, 2001).

2-2-2-2 Microspar:

Genetically, sparite is carbonate cement (orthosparite) or a product of recrystallization. Folk (1959) used rang size from 5 to more than 20 µm in diameter and Bathurst (1975) used rang size 5–50 µm, (Flugel, 2010). The term (microsparite) is a calcite matrix usually with equal crystal shape and uniform size of crystals. Two ways form microsparite: 1) the aggrading neomorphism (Recrystallization) created by the transformation of smaller High-Mg calcite crystals to larger calcite crystals. The clay content is an important factor and may hinder recrystallization if it being less than 2%. 2) Transformation of aragonite-dominated lime mud to microspar without micritic stage. Further criteria are equal grain shapes and boundaries, mosaic-like micro texture, tarnishes of organic matter or clays among the crystals, pits within the crystals, occasionally a patchy distribution in the micrite, generally loaf-shaped, euhedral and subhedral of calcite crystals. Pseudosparite is a coarse neomorphic fabrics (Calcite crystals is larger than 30µm) form by recrystallization, (Flugel, 2010).

2-2-3 Cement:

It is a chemical precipitate from solutions under supersaturation condition of the pore fluids comparably with the cement minerals, (Flugel, 2010).

2-3 Microfacies Analysis:-

2-3-1 Mudstone microfacies:

According to Dunham (1962), mudstone microfacies is a cryptocrystalline or microcrystalline calcite contain less than 10% of grains.. According to Tucker and Wright (2002), mudstone microfacies reflect deposition in a low-energy setting where grain production, especially by organisms, was reduced, maybe due to restricted conditions.

Mudstone microfacies in the studied intervals of Yamama Formation divided in to the following submicrofacies: **Dolomitic Bioclstic Mudstone submicrofacies, BioclsticMudstone submicrofacies,Mudstone–WackestoneMicrofacies,Bioclastic Mudstone – Wackestone Submicrofacies**

2-3-2-2Lithoclastic Mudstone–Wackestone Submicrofacies:

Characterized by fine grain bioclasts and lithoclasts associated with bioturbation. This microfacies was recognized in Tuba-2 Well at the depth (3912m, 3918m, and 4113m) and within Tuba-3 Well at depth (4131 and 4138m), Pl. (3-1 and 8-2).

2-3-3 Wackestone Microfacies:

It comprise of micrite and microspar groundmass and from (10-40) % of carbonate grains such as benthic foraminifera, algal fragments, echinoid, molluscas. This microfacies was divided in to the following submicrofacies:**Bioclastic Wackestone Submicrofacies,Algal Bioclastic Wackestone Submicrofacies,Foraminiferal Bioclstic Wackestone Submicrofacies**

2-3-4 Wackestone – Packstone with Sponge Spicules Microfacies:

This microfacies was recognized within Snd-2 Well at depth (4165m,4166m, 4197.5 m ,and 4252.5m) includes abundant of calcified sponge spicules, calcipheras, benthic foraminifera within microsparite groundmass,

2-3-5 Packstone Microfacies:

This Microfacies appear as dominated grains appearance, contain (40 %-90%) of carbonate grains within micrite and mirosparite ground mass. Carbonate grains involve peloids, oolites, cortoids, and skeletal grains such as benthic foraminifera, algae, echinoids, and mollusks. This microfacies was divided in to the following submicrofacies:

Bioclastic Packstone Submicrofacies, Peloidal Bioclastic Packstone Submicrofacies

2-3-6 Grainstone Microfacies:

This microfacies involve more than (90%) of grains locate within less than (10%) of micrite and microsparite groundmass.This microfacies as in packstone microfacies suffered from washing by sea waves and currents result in filtrate skeletal grains and remove the fine parts of groundmass. This microfacies was divided in to the following submicrofacies: **Pseudoolitic& Oolitic Grainstone Submicrofacies,and Peloidal Grainstone Submicrofacies,Bioclastic Grainstone Submicrofacies.**

Plate (1)

1 –Intraparticle porosity within benthic foraminifera and echinod fragment in peloidal bioclastic grainstone microfacies, Snd-2 Well,depth (4263m),X4, XPL.

2- Calcipheres and sponge spicules Snd-2 Well,depth (4165m), X4, XPL.

3- Dissilution, Tu-3 Well,depth (3887m),X4, XPL.

4-Resideu and dolomite crystals along stylolite, Tuba-3 well, depth (3910m),X4, XPL.

5- Stylolite and benthic foraminifera , Snd-2 Well, depth (4062m),X4,XPL.

6- Mechnical compaction(yellow arrow), dissilution enhanced intergranular (interparticle) porosity and form channel porosity , Snd-2 Well,depth (4087m),X4,XPL.

7- Syntaxial cement around echinoid fragment, Snd-2 Well,depth (4263m),X40, XPL.

8 –Intraparticle pores fill by cement in *Pseudocyclammina littus* ,blocky cement, Snd-2 Well, depth (4113.5 m),X4, XPL.

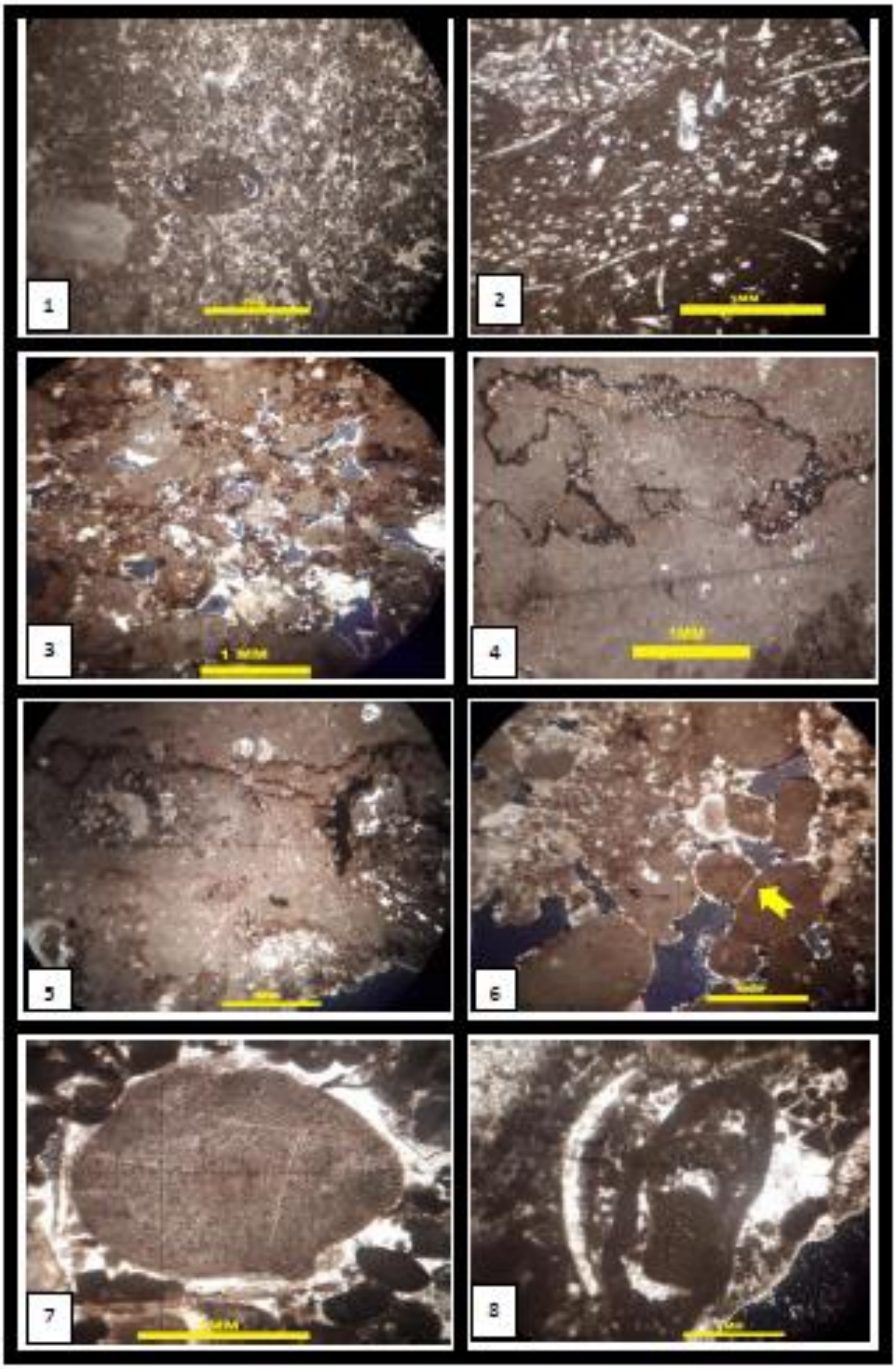
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Plate (2)

1- Red arrow *Salpingoporella*, 2- Yellow arrow Bisirial, 3-Black arrow Ostracod fragment in bioclastic packstone Tuba-3 Well, depth (4072m) ,X4 ,XPL.

2- *Actinoporella* sp,Tuba-3 Well , depth(4172m) ,X4 ,XPL.

3-Lithoclast and mechanical compaction, Tuba-3 Well, depth (4011m), X4,XPL.

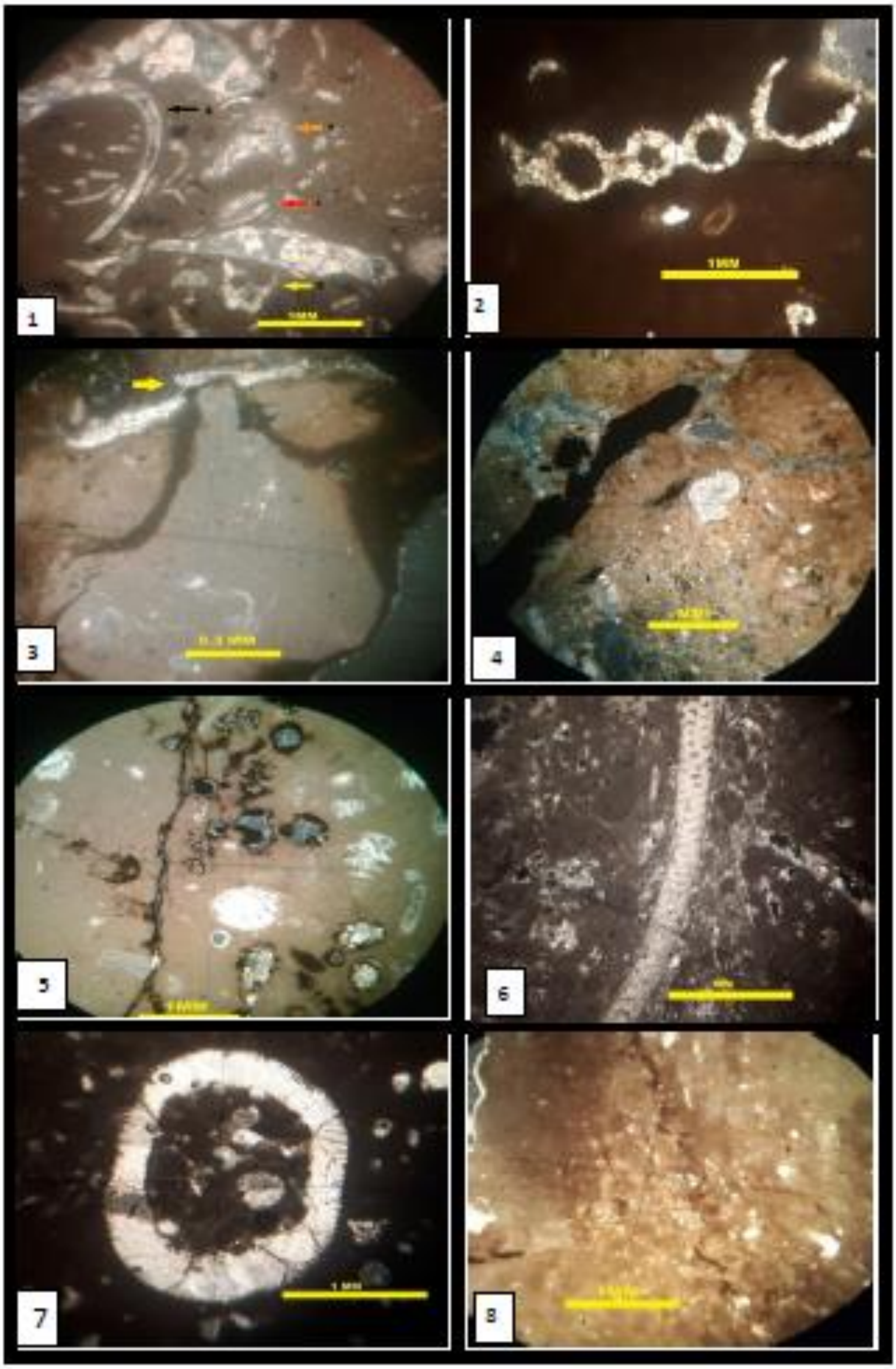
4 –Dissolution enhanced channel porosity filled by organic matter,Tuba-3 Well, depth (3863m), X4, XPL.

5- Fracture and mold porosity contain organic matter, Tuba-3 Well, depth (3940 m) ,X4 , XPL.

6-Neomorphisim wthin brachiopod fragment, Snd-2 Well, depth (4267 m), X4 , XPL.

7- Transversal section of *Salpingoporella* sp, Snd-2 Well, depth (4113.5 m),X4 , XPL.

8- Stylolite, Tuba-2 Well, depth (4036 m) ,X4 , XPL.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